(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 946 195 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
21.11.2018 Bulletin 2018/47

(21) Application number: **14704662.7**

(22) Date of filing: **14.01.2014**

(51) Int Cl.:
G01N 21/27 *(2006.01)* ***G01N 21/31*** *(2006.01)*
G01N 21/3504 *(2014.01)* ***G01N 21/359*** *(2014.01)*
A61B 5/08 *(2006.01)* ***G01J 3/10*** *(2006.01)*
G01J 3/28 *(2006.01)* ***G01J 3/42*** *(2006.01)*
G01N 33/497 *(2006.01)* *G01N 21/85 (2006.01)*
A61B 5/05 (2006.01) *A61M 16/10 (2006.01)*

(86) International application number:
PCT/IB2014/058259

(87) International publication number:
WO 2014/111847 (24.07.2014 Gazette 2014/30)

(54) **METHOD AND APPARATUS FOR MONITORING A LEVEL OF A GASEOUS SPECIES OF INTEREST**

VERFAHREN UND VORRICHTUNG ZUR ÜBERWACHUNG EINES FÜLLSTANDS EINER GASFÖRMIGEN SUBSTANZ VON INTERESSE

PROCÉDÉ ET APPAREIL DE SURVEILLANCE DU NIVEAU D'UNE ESPÈCE GAZEUSE D'INTÉRÊT

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **17.01.2013 US 201361753484 P**

(43) Date of publication of application:
25.11.2015 Bulletin 2015/48

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EP 2 946 195 B1

Description

BACKGROUND

1. Field

[0001] The present disclosure pertains to a method and apparatus for enhanced gas measurement by infrared spectroscopy through implementing a near-infrared electromagnetic radiation source to generate reference electromagnetic radiation.

2. Description of the Related Art

[0002] Systems that perform the measurement of gas levels based on the measurement of infrared electromagnetic radiation that has passed through the gas are known. Typically, in such systems that measure gas levels in a respiratory circuit, electromagnetic radiation emitted by an individual radiation source in the mid-infrared range is used for both measurement and a reference to compensate for optical loss (*e.g.,* scattering, blockage, and/or other loss). These devices typically employ two separate sensors for measurement intensity in the mid-infrared range.

[0003] Patent application publication EP 2944945 A1 discloses a laser-type gas analyzer that can measure the gas concentration of a first gas in a mid-infrared region and of a second gas in a near-infrared region. The gas analyzer includes means for measuring water concentration and a light amount decrement due to dust. It further includes a gas concentration correcting unit for correcting the gas concentration measurements using the water concentration and the light amount decrement.

[0004] Document WO 2012/153209 A1 discloses an infrared detector that includes a radiation source configured to emit electromagnetic radiation. The detector includes a source monitoring apparatus configured to generate output signals related to electrical resistance through the radiation source. The output signals are used to account for radiation source temperature in measurements by the detector. The output signals may be used in the provision of power to the radiation source to maintain the temperature of the detector at a beneficial level. The detector is configured to monitor a level of a gaseous molecular species within a flow of breathable gas.

[0005] US 5,942,755 A relates to an infrared optical gas-measuring system with two infrared radiation sources and with at least one multispectral sensor. The system is suitable for determining the concentrations of different components of a gas flow. The two infrared radiation sources radiate in different spectral ranges with two different cycle frequencies. The rays emitted are first passed through a radiation coupler, after which they pass through the gas flow to be measured, which is limited by windows, at right angles to the direction of flow. The rays finally enter a multispectral sensor, of which there is at least one, for measuring the intensity.

[0006] Patent application publication US 2008/315102 A1 describes a method and an apparatus for detecting, by absorption spectroscopy, an isotopic ratio of a sample, by passing first and second laser beams of different frequencies through the sample. Two IR absorption cells are used, a first containing a reference gas of known isotopic ratio and the second containing a sample of unknown isotopic ratio. An interlacer or reflective chopper may be used so that as the laser frequencies are scanned the absorption of the sample cell and the reference cell are detected alternately. This ensures that the apparatus is continuously calibrated and rejects the baseline noise when phase sensitive detection is used.

SUMMARY

[0007] The scope of the invention is defined by the independent claims. Advantageous embodiments are defined by the dependent claims.

[0008] Accordingly, one or more aspects of the present disclosure relate to a detector configured to monitor a level of a gaseous molecular species within a flow of breathable gas. The detector comprises a first source, a second source, source optics, sensor optics, a first radiation sensor, a second radiation sensor, and a processor. The first source is configured to emit mid-infrared electromagnetic radiation. The second source is configured to emit near-infrared electromagnetic radiation. The source optics are configured to combine mid-infrared electromagnetic radiation emitted by the first source and near-infrared electromagnetic radiation emitted by the second source into a coaxial beam, and to direct the coaxial beam across a flow path of a flow of breathable gas that communicates with an airway of a subject. The sensor optics are configured to receive electromagnetic radiation in the coaxial beam that has traversed the flow path, and to divide the received electromagnetic radiation into first radiation that includes mid-infrared electromagnetic radiation and second radiation that includes near-infrared electromagnetic radiation. The first radiation sensor is configured to receive the first radiation, and to generate output signals conveying information related to a parameter of the mid-infrared electromagnetic radiation in the first radiation. The second radiation sensor is configured to receive the second radiation, and to generate output signals conveying information related to a parameter of the near-infrared electromagnetic radiation in the second radiation. The processor is configured to determine a level of a gaseous molecular species within the flow of breathable gas in the flow path based on the output signals generated by the first radiation sensor and the second radiation sensor such that the output signals generated by the second radiation sensor are implemented to compensate optical loss through the flow path in the output signals generated by the first radiation sensor. The detector further comprises a source monitoring apparatus configured to generate output signals conveying information related to electrical resistance through the first source, and wherein the processor is further configured such that the determination of the level of the gaseous molecular species is further based on the output signals generated by the source monitoring apparatus to account for the electrical resistance through the first source.

[0009] Yet another aspect of the present disclosure relates to a method of monitoring a level of a gaseous molecular species within a flow of breathable gas with a detector that includes a first source, a second source, source optics, sensor optics, a first radiation sensor, a second radiation sensor, and a processor. The method comprises emitting mid-infrared electromagnetic radiation from the first source; emitting near-infrared electromagnetic radiation from the second source; combining, with the source optics, mid-infrared electromagnetic radiation emitted by the first source and near-infrared electromagnetic radiation emitted by the second source into a coaxial beam; directing, with the source optics, the coaxial beam across a flow path of the flow of breathable gas that communicates with an airway of a subject; dividing, with the sensor optics, electromagnetic radiation in the coaxial beam that has traversed the flow path into first radiation that includes mid-infrared electromagnetic radiation and second radiation that includes near-infrared electromagnetic radiation; generating, with the first radiation sensor, output signals conveying information related to a parameter of the mid-infrared electromagnetic radiation in the first radiation; generating, with the second radiation sensor, output signals conveying information related to a parameter of the near-infrared electromagnetic radiation in the second radiation; and determining, by the processor, a level of a gaseous molecular species within the flow of breathable gas in the flow path based on the output signals generated by the first radiation sensor and the second radiation sensor such that the output signals generated by the second radiation sensor are implemented to compensate optical loss through the flow path in the output signals generated by the first radiation sensor. The detector further includes a source monitoring apparatus, wherein the method further comprises generating, with the source monitoring apparatus, output signals conveying information related to electrical resistance through the first source, and wherein the determination of the level of the gaseous molecular species is further based on the output signals generated by the source monitoring apparatus to account for the electrical resistance through the first source.

[0010] These and other objects, features, and characteristics of the present disclosure, as well as the methods of operation and functions of the related elements of structure and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 illustrates a detector configured to measure a level of a gaseous molecular species in a flow of breathable gas; and

FIG. 2 illustrates a method of measuring a level of gaseous molecular species in a flow of breathable gas.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0012] As used herein, the singular form of "a", "an", and "the" include plural references unless the context clearly dictates otherwise. As used herein, the statement that two or more parts or components are "coupled" shall mean that the parts are joined or operate together either directly or indirectly, i.e., through one or more intermediate parts or components, so long as a link occurs. As used herein, "directly coupled" means that two elements are directly in contact with each other. As used herein, "fixedly coupled" or "fixed" means that two components are coupled so as to move as one while maintaining a constant orientation relative to each other.

[0013] As used herein, the word "unitary" means a component is created as a single piece or unit. That is, a component that includes pieces that are created separately and then coupled together as a unit is not a "unitary" component or body. As employed herein, the statement that two or more parts or components "engage" one another shall mean that the parts exert a force against one another either directly or through one or more intermediate parts or components. As employed herein, the term "number" shall mean one or an integer greater than one (i.e., a plurality).

[0014] Directional phrases used herein, such as, for example and without limitation, top, bottom, left, right, upper, lower, front, back, and derivatives thereof, relate to the orientation of the elements shown in the drawings and are not limiting upon the claims unless expressly recited therein.

[0015] FIG. 1 illustrates a detector 10 configured to measure a level of a gaseous molecular species in a flow of breathable gas. The gaseous molecular species may be carbon dioxide, nitrous oxide, water vapor, anesthetic gas, and/or other gaseous molecular species. For convenience, particular reference is made below to measurement of carbon dioxide. It will be appreciated that such references are not limiting, and that the principles described with respect to the measurement of carbon dioxide could be practiced in the measurement of other gaseous molecular species without departing from the scope of this disclosure. Further, description herein of detector 10 being configured to measure the level of a gaseous molecular species in a respiratory therapy context is not limiting. The principles described herein are equally applicable to other systems that perform gas level measurement in other contexts (e.g., air quality detectors, automobile emissions detectors, and/or other systems).

[0016] In one embodiment, detector 10 includes a "U" shaped housing 29 enclosing a source assembly 12, a radiation sensor assembly 14, and/or other components. Two opposing legs of the "U" shaped housing 29 define opposite sides of a gap therebetween, with the source assembly 12 disposed in one leg on one side of the gap (source side) and the radiation sensor assembly 14 disposed in the opposing leg on the opposite side of the gap (detector side). A hollow airway assembly 16 can be removably docked in the U between the opposing legs. Detector 10 also includes self-contained electronics (some of which are shown in FIG. 1 and described below) disposed within the housing 29.

[0017] Airway assembly 16 forms a flow path 18 for a flow of breathable gas that communicates with the airway of a subject. Airway assembly 14 has windows 28 disposed on opposite sides such that infrared radiation entering flow path 18 via window 28 on one side of airway assembly 16 passes through the flow of breathable gas (patient respiration) in airway assembly 16 and exits via window 28 on the opposite side. Airway assembly 14 may be either a disposable unit or a reusable unit that removably clips into the gap in "U" shaped housing 29, with source assembly 12 and radiation sensor assembly 14 being generally arranged such that infrared radiation emanating from source assembly 12 is directed across the gap through the gas sample in airway assembly 16 to impinge upon radiation sensor assembly 14. The airway windows 28 may be formed of plastic film (disposable version), sapphire (reusable version) and/or other materials.

[0018] Source assembly 12 includes a first radiation source 20, a second radiation source 22, source optics 24, a power source 26, a source monitoring apparatus 27, and/or other components. First radiation source 20 is configured to emit broadband radiation including mid-infrared electromagnetic radiation. Infrared radiation generally refers to radiation occupying a band of wavelengths in the optical spectrum between 0.7μm and 300μm. Mid-infrared may generally refer to a mid-wavelength subset of the infrared radiation band between 3μm and 8μm. Mid-infrared radiation emitted by first radiation source 20 includes a gas wavelength (λ_{GAS}), at which radiation is absorbed by a gaseous molecular species of interest. The gaseous molecular species may include carbon dioxide, nitrous oxide, water vapor, anesthetic gases, and/or other gaseous molecular species. The radiation source 18 may operate substantially as a blackbody for at least a portion of the spectrum.

[0019] Second radiation source 22 is configured to emit electromagnetic radiation including near-infrared electromagnetic radiation. Near-infrared electromagnetic radiation may generally refer to a short-wavelength subset of the infrared radiation band between, for example, 0.7μm and 3μm. Sources that emit electromagnetic radiation in this range may be relatively inexpensive, power efficient, and rugged. For example, second radiation source 22 may include a light emitting diode, laser diode, and/or other sources.

[0020] Source optics 24 are configured to combine mid-infrared electromagnetic radiation emitted by first radiation source 20 and near-infrared electromagnetic radiation emitted by second radiation source 22 into a coaxial beam. Source optics 24 are configured to direct the coaxial beam across flow path 18 formed by airway assembly 14. Source optics 24 may include a lens 30, a beam combiner 32, a window 34, and/or other components. Lens 30 may be a sapphire half-ball lens that gathers and collimates the emitted radiation from first radiation source 20, directing it toward beam combiner 32. Beam combiner 32 is configured to combine electromagnetic radiation emitted by first radiation source 20 and electromagnetic radiation emitted by second radiation source 22 into the coaxial beam. The coaxial beam is directed from beam combiner 32 across the gap and through the airway assembly 16 towards the radiation sensor assembly 14 via window 32. The electromagnetic radiation is combined into a coaxial beam so that any materials present in flow path 18 will be in the path of the electromagnetic radiation emitted by first radiation source 20 and the electromagnetic radiation emitted by second radiation source 22.

[0021] Power source 26 may be configured to provide power to first radiation source 20, second radiation source 22, and/or other components. Power source 26 may include, for example, a battery, a capacitor, a power converter, a port or connector configured to receive power from an external source (*e.g.,* a wall socket, a monitor, and/or other external power sources), and/or other sources of power. In some embodiments, power source 26 is configured to deliver power in a pulsed manner, in order to cause the radiation emitted by first radiation source 20 to be pulsed. To accomplish this, power source 26 may vary the potential, current, power, and/or other parameters of the electrical power provided to first radiation source 20. In one embodiment, the power is provided to first radiation source 20 such that first radiation source 20 is pulsed at about 100Hz to produce a periodically varying mid-infrared signal with a period of about 10 milliseconds.

[0022] The source monitoring apparatus 27 is configured to generate output signals conveying information related to one or more parameters of power through first radiation source 20. Such parameters may include, for example, current, potential, power, resistance, induction, and/or other parameters. In some embodiments, the resistance through first radiation source 20 is of particular interest. As such, the one or more parameters may include resistance itself, and/or other parameters from which resistance through first radiation source 20 can be determined. The source monitoring apparatus 27 may be integrated with power source 26 and/or first radiation source 20, or may be formed separately as illustrated in FIG. 1.

[0023] A processor 36 is configured to provide information processing capabilities in detector 10. As such, processor 36 may include one or more of a digital processor, an analog processor, a digital circuit designed to process information, an analog circuit designed to process information, a state machine, and/or other mechanisms for electronically processing information. Although processor 36 is shown in FIG. 1 as a single entity, this is for illustrative purposes only. In some implementations, processor 36 may include a plurality of processing units. These processing units may be physically located within the same device, or processor 36 may represent processing functionality of a plurality of devices operating in coordination. The operation of processor 36 is discussed further below. The illustration of processor 36 as being included within detector 10 is not intended to be limiting. Some or all of the functionality attributed herein to processor 36 may be provided by one or more components disposed outside of detector 10.

[0024] Radiation sensor assembly 14 includes sensor optics 38, a first sensor 40, a second sensor 42, and/or other components. Sensor optics 38 are configured to direct electromagnetic radiation that has passed through flow path 18 formed by airway assembly 16 onto first sensor 40 and second sensor 42. In some embodiments, sensor optics 38 comprise a lens assembly 44, a beam splitter assembly 46, and/or other optical components. Lens assembly 44, which in one embodiment includes an AR-coated (Anti-Reflective coated) silicon plano-convex lens, focuses the infrared radiation reaching it from the source assembly 12, and directs the electromagnetic radiation toward first sensor 40 and second sensor 42 via beam splitter assembly 46. In beam splitter assembly 46, a dichroic beam-splitter is positioned to reflect mid-infrared radiation containing the molecular species of interest wavelength λ_{GAS} towards first sensor 40, and to pass near infrared electromagnetic radiation towards second sensor 42. A narrow-band first optical filter 48 that passes λ_{GAS} is positioned in front of first sensor 40. First sensor 40 generates output signals conveying information related to intensity and/or other parameters of the mid-infrared electromagnetic radiation that becomes incident thereon. First sensor 40 may include, for example, a PbSe substrate, a pyrometer, a thermopile, and/or other sensor devices. Second sensor 42 is configured to generate output signals conveying information related to intensity and/or other parameters of the near-infrared electromagnetic radiation that becomes incident thereon. Second sensor 42 may include, for example, a photodiode, such as InGaAs or Ge, or other sensor device. The sensor device included in second sensor 42 may be less costly, more rugged, and/or different in other ways from the sensor device included in first sensor 40. This may enhance detector 10 with respect to conventional detectors, which usually require two devices capable of detecting electromagnetic radiation within the mid-infrared range.

[0025] The basic principle of operation behind Capnometry/Capnography and/or detection of other gaseous molecular species via detector 10 is that infrared radiation in a band around an absorption wavelength for a gaseous molecular species of interest (*e.g.*, 4.275μm for carbon dioxide) experiences increasing absorption (when traveling a fixed-length path through a sample gas) with increasing concentration of the gaseous molecular species - according to a reliably repeatable relationship. On the other hand, the absorption near-infrared radiation under the same conditions is essentially unaffected by the molecular species of interest.

[0026] When the coaxial beam of electromagnetic radiation from source assembly 12 passes through the body of gas in airway assembly 14, mid-infrared radiation at λ_{GAS} is attenuated according to the concentration of the molecular species of interest in the body of gas. Electromagnetic radiation in the near-infrared range, however, is unaffected by any such molecular species of interest in the body of gas. Therefore, changes in intensity of the mid-infrared electromagnetic radiation at λ_{GAS} that has traversed flow path 18 without an accompanying drop in intensity of the near-infrared electromagnetic radiation that has traversed flow path 18 indicates absorption of the mid-infrared electromagnetic radiation by the gaseous molecular species. On the other hand, optical loss within flow path 18 that impacts both the mid-infrared and the near-infrared range indicates the presence of a substance (*e.g.*, water condensation or droplets and/or other substances) that has scattered or blocked the electromagnetic radiation in both the near-infrared and mid-infrared ranges. As such, the intensity (or related parameter(s)) of electromagnetic radiation in the near-infrared range are used to normalize the intensity (or related parameter(s)) of electromagnetic radiation in the mid-infrared range to discern between absorption by the molecular species of interest and optical loss to scattering or blockage within flow path 18. The implementation in this manner of near-infrared electromagnetic radiation as a reference, rather than another wavelength in the mid-infrared range, may facilitate more robust compensation for optical loss within flow path 18.

[0027] Aside from optical loss within flow path 18, intensity (or related parameter(s)) of the mid-infrared electromagnetic radiation received at sensor assembly 14 may be impacted by fluctuations in irradiance of first source 20. However, such fluctuations tend to coincide with corresponding fluctuations in temperature of first radiation source 20. Temperature of first radiation source 20 may be determined as a function of electrical resistance through first radiation source 20. As such, the output signals generated by source monitoring apparatus 27 facilitate compensation for fluctuations in irradiance of first radiation source 20 in determining the level of the gaseous molecular species within flow path 18 based on the output signals generated by first sensor 40. For example, irradiance may be determined as a function of resistance through first radiation source 20, potential across first radiation source 20, current through first radiation source 20, and/or other parameters.

[0028] Processor 36 is configured to determine a level of a gaseous molecular species within the flow of breathable gas in the flow path based on the output signals generated by first sensor 40 and second sensor 42. This includes implementing the output signals generated by second sensor 42 to compensate for optical loss through flow path 18. Processor 36 is further configured to determine the level of the gaseous molecular species based on the output signals generated by source monitoring apparatus 27. This effectively adjusts the level determination for the irradiance of first radiation source 20. Processor 36 may be configured to determine the level of the gaseous molecular species based on the output signals of first sensor 40, second sensor 42, and/or source monitoring apparatus 27 with one or more of a function in which output signals are implemented as variable inputs, a look-up table, and/or through other computational techniques.

[0029] FIG. 2 illustrates a method 50 of monitoring a level of a gaseous molecular species within a flow of breathable gas. The operations of method 50 presented below are intended to be illustrative. In some embodiments, method 50 may be accomplished with one or more additional operations not described, and/or without one or more of the operations discussed. Additionally, the order in which the operations of method 50 are illustrated in FIG. 2 and described below is not intended to be limiting. In some embodiments, method 50 may be implemented in a detector similar to or the same as detector 10 (shown in FIG. 1 and described herein).

[0030] At an operation 52, mid-infrared electromagnetic radiation is emitted. In some embodiments, operation 52 is performed by a first radiation source the same as or similar to first radiation source 20 (shown in FIG. 1 and described herein).

[0031] At an operation 53, output signals conveying information related to electrical resistance through the first source are generated. In some embodiments, operation 53 is performed by a source monitoring apparatus the same as or similar to source monitoring apparatus 27 (shown in FIG. 1 and described herein).

[0032] At an operation 54, near-infrared electromagnetic radiation is emitted. In some embodiments, operation 54 is performed by a second radiation source the same as or similar to second radiation source 22 (shown in FIG. 1 and described herein).

[0033] At an operation 56, mid-infrared electromagnetic radiation emitted at operation 52 and near-infrared electromagnetic radiation emitted at operation 54 are combined into a coaxial beam. In some embodiments, operation 56 is performed by source optics the same as or similar to source optics 24 (shown in FIG. 1 and described herein).

[0034] At an operation 58, the coaxial beam is directed across a flow path of the flow of breathable gas that communicates with an airway of the subject. In some embodiments, operation 58 is performed by source optics the same as or similar to source optics 24 (shown in FIG. 1 and described herein).

[0035] At an operation 60, electromagnetic radiation in the coaxial beam that has traversed the flow path is divided into first radiation that includes mid-infrared electromagnetic radiation and second radiation that includes near-infrared electromagnetic radiation. In some embodiments, operation 60 is performed by sensor optics the same as or similar to sensor optics 38 (shown in FIG. 1 and described herein).

[0036] At an operation 62, output signals conveying information related to a parameter of the mid-infrared electromagnetic radiation in the first radiation are generated. In some embodiments, operation 62 is performed by a first sensor the same as or similar to first sensor 40 (shown in FIG. 1 and described herein).

[0037] At an operation 64, output signals conveying information related to a parameter of the near-infrared electromagnetic radiation in the second radiation are generated. In some embodiments, operation 64 is performed by a second sensor the same as or similar to second sensor 42 (shown in FIG. 1 and described herein).

[0038] At an operation 66, a level of gaseous molecular species within the flow of breathable gas is determined. The level determination may be made based on the output signals generated at one or more of operation 62, operation 64, and/or 53. Determination of the level of the gaseous molecular species based on the output signals generated at operation 64 compensates for optical loss through the flow path. Determination of the level of the gaseous molecular species based on the output signals generated at operation 53 effectively adjusts the level determination for the irradiance of the first source. In some embodiments operation 66 is performed by a processor the same as or similar to processor 36 (shown in FIG. 1 and described herein).

[0039] In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" or "including" does not exclude the presence of elements or steps other than those listed in a claim. In a device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. In any device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain elements are recited in mutually different dependent claims does not indicate that these elements cannot be used in combination.

[0040] Although the description provided above provides detail for the purpose of illustration based on what is currently considered to be the most practical and preferred embodiments, it is to be understood that such detail is solely for that purpose and that the disclosure is not limited to the expressly disclosed embodiments, but, on the contrary, is intended to cover modifications and equivalent arrangements that are within the scope of the appended claims. For example, it is to be understood that the present disclosure contemplates that, to the extent possible, one or more features of any embodiment can be combined with one or more features of any other embodiment.

Claims

1. A detector (10) configured to monitor a level of a gaseous molecular species within a flow of breathable gas, the detector comprising:

a first source (20) configured to emit mid-infrared electromagnetic radiation;
a second source (22) configured to emit near-infrared electromagnetic radiation;
source optics (24) configured to combine mid-infrared electromagnetic radiation emitted by the first source and near-infrared electromagnetic radiation emitted by the second source into a coaxial beam, and to direct the coaxial beam across a flow path (18) of a flow of breathable gas that communicates with an airway of a subject;
sensor optics (38) configured to receive electromagnetic radiation in the coaxial beam that has traversed the flow path, and to divide the received electromagnetic radiation into first radiation that includes mid-infrared electromagnetic radiation and second radiation that includes near-infrared electromagnetic radiation;
a first radiation sensor (40) configured to receive the first radiation, and to generate output signals conveying information related to a parameter of the mid-infrared electromagnetic radiation in the first radiation;
a second radiation sensor (42) configured to receive the second radiation, and to generate output signals conveying information related to a parameter of the near-infrared electromagnetic radiation in the second radiation; and
a processor (36) configured to determine a level of a gaseous molecular species within the flow of breathable gas in the flow path based on the output signals generated by the first radiation sensor and the second radiation sensor such that the output signals generated by the second radiation sensor are implemented to compensate optical loss through the flow path in the output signals generated by the first radiation sensor;

characterized in that the detector further comprises a source monitoring apparatus (27) configured to generate output signals conveying information related to electrical resistance through the first source, and wherein the processor is further configured such that the determination of the level of the gaseous molecular species is further based on the output signals generated by the source monitoring apparatus to account for the electrical resistance through the first source.

2. The detector (10) of claim 1, wherein determining the level of the gaseous molecular species based on the output signals generated by the source monitoring apparatus (27) effectively adjusts the level determination for the irradiance of the first source (20).

3. The detector (10) of claim 1, wherein the second radiation sensor (42) includes a photodiode.

4. The detector (10) of claim 1, wherein the second source (22) includes a light emitting diode or laser diode.

5. A method of monitoring a level of a gaseous molecular species within a flow of breathable gas with a detector (10) that includes a first source (20), a second source (22), source optics (24), sensor optics (38), a first radiation sensor (40), a second radiation sensor (42), and a processor (36), the method comprising:

emitting mid-infrared electromagnetic radiation from the first source (20);
emitting near-infrared electromagnetic radiation from the second source (22);
combining, with the source optics (24), mid-infrared electromagnetic radiation emitted by the first source (20) and near-infrared electromagnetic radiation emitted by the second source (22) into a coaxial beam;
directing, with the source optics (24), the coaxial beam across a flow path (18) of the flow of breathable gas that communicates with an airway of a subject;
dividing, with the sensor optics (38), electromagnetic radiation in the coaxial beam that has traversed the flow path (18) into first radiation that includes mid-infrared electromagnetic radiation and second radiation that includes near-infrared electromagnetic radiation;
generating, with the first radiation sensor (40), output signals conveying information related to a parameter of the mid-infrared electromagnetic radiation in the first radiation;
generating, with the second radiation sensor (42), output signals conveying information relat-

ed to a parameter of the near-infrared electromagnetic radiation in the second radiation; and determining, by the processor (36), a level of a gaseous molecular species within the flow of breathable gas in the flow path (18) based on the output signals generated by the first radiation sensor (40) and the second radiation sensor (42) such that the output signals generated by the second radiation sensor (42) are implemented to compensate optical loss through the flow path (18) in the output signals generated by the first radiation sensor (40);

characterized in that the detector further includes a source monitoring apparatus (27), wherein the method further comprises generating, with the source monitoring apparatus (27), output signals conveying information related to electrical resistance through the first source (20), and wherein the determination of the level of the gaseous molecular species is further based on the output signals generated by the source monitoring apparatus (27) to account for the electrical resistance through the first source (20).

6. The method of claim 5, wherein determining the level of the gaseous molecular species based on the output signals generated by the source monitoring apparatus (27) effectively adjusts the level determination for the irradiance of the first source (20).

7. The method of claim 5, wherein the second radiation sensor (42) includes a photodiode.

8. The method of claim 5, wherein the second source (22) includes a light emitting diode or a laser diode.

Patentansprüche

1. Detektor (10), welcher konfiguriert ist, einen Füllstand einer gasförmigen molekularen Substanz innerhalb eines Stroms von atembarem Gas zu überwachen, wobei der Detektor umfasst:

eine erste Quelle (20), welche konfiguriert ist, elektromagnetische Strahlung im mittleren Infrarot abzugeben;

eine zweite Quelle (22), welche konfiguriert ist, elektromagnetische Strahlung im nahen Infrarot abzugeben;

Quelloptik (24), welche konfiguriert ist, elektromagnetische Strahlung im mittleren Infrarot, welche von der ersten Quelle abgegeben wird, und elektromagnetische Strahlung im nahen Infrarot, welche von der zweiten Quelle abgegeben wird, in einen koaxialen Strahl zu kombinieren, und den koaxialen Strahl durch eine Stromlinie (18) eines Stroms von atembarem Gas, welches mit einem Luftweg eines Subjekts kommuniziert, zu richten;

Sensoroptik (38), welche konfiguriert ist, elektromagnetische Strahlung in dem koaxialen Strahl, welcher die Stromlinie durchquert hat, zu empfangen, und die empfangene elektromagnetische Strahlung in erste Strahlung, welche elektromagnetische Strahlung im mittleren Infrarot beinhaltet, und zweite Strahlung, welche elektromagnetische Strahlung im nahen Infrarot beinhaltet, aufzuteilen;

einen ersten Strahlungssensor (40), welcher konfiguriert ist, die erste Strahlung zu empfangen, und Ausgangssignale zu erzeugen, welche auf einen Parameter der elektromagnetischen Strahlung im mittleren Infrarot bezogene Informationen in der ersten Strahlung übertragen;

einen zweiten Strahlungssensor (42), welcher konfiguriert ist, die zweite Strahlung zu empfangen, und Ausgangssignale zu erzeugen, welche auf einen Parameter der elektromagnetischen Strahlung im nahen Infrarot bezogene Informationen in der zweiten Strahlung übertragen; und

einen Prozessor (36), welcher konfiguriert ist, einen Füllstand einer gasförmigen molekularen Substanz innerhalb des Stroms von atembarem Gas in der Stromlinie auf Basis der Ausgangssignale, welche von dem ersten Strahlungssensor und dem zweiten Strahlungssensor erzeugt wurden, zu bestimmen, sodass die Ausgangssignale, welche von dem zweiten Strahlungssensor erzeugt wurden, implementiert werden, um optische Verluste durch die Stromlinie in den Ausgangssignalen, welche von dem ersten Strahlungssensor erzeugt wurden, zu kompensieren;

dadurch gekennzeichnet, dass der Detektor weiter eine Quellenüberwachungsvorrichtung (27) umfasst, welche konfiguriert ist, Ausgangssignale zu erzeugen, welche auf elektrischen Widerstand durch die erste Quelle bezogene Informationen übertragen, und wobei der Prozessor weiter konfiguriert ist, sodass die Bestimmung des Füllstands der gasförmigen molekularen Substanz weiter auf den Ausgangssignalen basiert, welche von der Quellenüberwachungsvorrichtung erzeugt wurden, um den elektrischen Widerstand durch die erste Quelle zu berücksichtigen.

2. Detektor (10) nach Anspruch 1, wobei Bestimmen des Füllstands der gasförmigen molekularen Substanz auf Basis der Ausgangssignale, welche von der Quellenüberwachungsvorrichtung (27) erzeugt wurden, die Füllstandsbestimmung für die Bestrahlungsstärke der ersten Quelle (20) effektiv anpasst.

3. Detektor (10) nach Anspruch 1, wobei der zweite Strahlungssensor (42) eine Fotodiode beinhaltet.

4. Detektor (10) nach Anspruch 1, wobei die zweite Quelle (22) eine lichtemittierende Diode oder Laserdiode beinhaltet.

5. Verfahren zum Überwachen eines Füllstands einer gasförmigen molekularen Substanz innerhalb eines Stroms von atembarem Gas mit einem Detektor (10), welcher eine erste Quelle (20), eine zweite Quelle (22), Quelloptik (24), Sensoroptik (38), einen ersten Strahlungssensor (40) einen zweiten Strahlungssensor (42) und einen Prozessor (36) beinhaltet, wobei das Verfahren umfasst:

Abgeben von elektromagnetischer Strahlung im mittleren Infrarot von der ersten Quelle (20);
Abgeben von elektromagnetischer Strahlung im nahen Infrarot von der zweiten Quelle (22);
Kombinieren, mit der Quelloptik (24), von elektromagnetischer Strahlung im mittleren Infrarot, welche von der ersten Quelle (20) abgegeben wird, und elektromagnetischer Strahlung im nahen Infrarot, welche von der zweiten Quelle (22) abgegeben wird, in einen koaxialen Strahl;
Richten, mit der Quelloptik (24), des koaxialen Strahls durch eine Stromlinie (18) des Stroms von atembarem Gas, welcher mit dem Luftweg eines Subjekts kommuniziert;
Aufteilen, mit der Sensoroptik (38), von elektromagnetischer Strahlung in dem koaxialen Strahl, welcher die Stromlinie (18) durchquert hat, in erste Strahlung, welche elektromagnetische Strahlung im mittleren Infrarot beinhaltet, und zweite Strahlung, welche elektromagnetische Strahlung im nahen Infrarot beinhaltet;
Erzeugen, mit dem ersten Strahlungssensor (40), von Ausgangssignalen, welche auf einen Parameter der elektromagnetischen Strahlung im mittleren Infrarot bezogene Informationen in der ersten Strahlung übertragen;
Erzeugen, mit dem zweiten Strahlungssensor (42), von Ausgangssignalen, welche auf einen Parameter der elektromagnetischen Strahlung im nahen Infrarot bezogene Informationen in der zweiten Strahlung übertragen; und
Bestimmen, mittels des Prozessors (36), eines Füllstands einer gasförmigen molekularen Substanz innerhalb des Stroms von atembarem Gas in der Stromlinie (18) auf Basis der Ausgangssignale, welche von dem ersten Strahlungssensor (40) und dem zweiten Strahlungssensor (42) erzeugt wurden, sodass die Ausgangssignale, welche von dem zweiten Strahlungssensor (42) erzeugt wurden, implementiert werden, um optische Verluste durch die Stromlinie (18) in den Ausgangssignalen, welche von dem ersten Strahlungssensor (40) erzeugt wurden, zu kompensieren;
dadurch gekennzeichnet, dass der Detektor weiter eine Quellenüberwachungsvorrichtung (27) beinhaltet,
wobei das Verfahren weiter Erzeugen, mit der Quellenüberwachungsvorrichtung (27), von Ausgangssignalen umfasst, welche auf elektrischen Widerstand durch die erste Quelle (20) bezogene Informationen übertragen,
und wobei die Bestimmung des Füllstands der gasförmigen molekularen Substanz weiter auf den Ausgangssignalen basiert, welche von der Quellenüberwachungsvorrichtung (27) erzeugt wurden, um den elektrischen Widerstand durch die erste Quelle (20) zu berücksichtigen.

6. Verfahren nach Anspruch 5, wobei Bestimmen des Füllstands der gasförmigen molekularen Substanz auf Basis der Ausgangssignale, welche von der Quellenüberwachungsvorrichtung (27) erzeugt wurden, die Füllstandsbestimmung für die Bestrahlungsstärke der ersten Quelle (20) effektiv anpasst.

7. Verfahren nach Anspruch 5, wobei der zweite Strahlungssensor (42) eine Fotodiode beinhaltet.

8. Verfahren nach Anspruch 5, wobei die zweite Quelle (22) eine lichtemittierende Diode oder eine Laserdiode beinhaltet.

Revendications

1. Détecteur (10) configuré pour surveiller un niveau d’une espèce moléculaire gazeuse dans un flux de gaz respirable, le détecteur comprenant :

une première source (20) configurée pour émettre un rayonnement électromagnétique d’infrarouge moyen ;
une seconde source (22) configurée pour émettre un rayonnement électromagnétique du proche infrarouge ;
une optique de source (24) configurée pour combiner le rayonnement électromagnétique d’infrarouge moyen émis par la première source et le rayonnement électromagnétique du proche infrarouge émis par la seconde source en un faisceau coaxial et pour diriger le faisceau coaxial en travers d’un trajet d’écoulement (18) d’un flux de gaz respirable qui communique avec une voie aérienne d’un sujet ;
une optique de détecteur (38) configurée pour recevoir un rayonnement électromagnétique dans le faisceau coaxial qui a traversé le trajet d’écoulement et diviser le rayonnement électromagnétique reçu en premier rayonnement qui

comprend un rayonnement électromagnétique d'infrarouge moyen et un second rayonnement qui comprend un rayonnement électromagnétique du proche infrarouge ;

un premier capteur de rayonnement (40) configuré pour recevoir le premier rayonnement et générer des signaux de sortie acheminant des informations en rapport avec un paramètre du rayonnement électromagnétique d'infrarouge moyen dans le premier rayonnement ;

un second capteur de rayonnement (42) configuré pour recevoir le second rayonnement et générer des signaux de sortie acheminant des informations en rapport avec un paramètre du rayonnement électromagnétique du proche infrarouge dans le second rayonnement ; et

un processeur (36) configuré pour déterminer un niveau d'une espèce moléculaire gazeuse dans le flux de gaz respirable du trajet d'écoulement sur la base des signaux de sortie générés par le premier capteur de rayonnement et le second capteur de rayonnement de sorte que les signaux de sortie générés par le second capteur de rayonnement soient mis en oeuvre pour compenser une perte optique à travers le trajet d'écoulement dans les signaux de sortie générés par le premier capteur de rayonnement ;

caractérisé en ce que le détecteur comprend en outre un appareil de surveillance de source (27) configuré pour générer des signaux de sortie acheminant des informations en rapport avec la résistance électrique à travers la première source et dans lequel le processeur est en outre configuré de sorte que la détermination du niveau de l'espèce moléculaire gazeuse est en outre basée sur les signaux de sortie générés par l'appareil de surveillance de source afin de tenir compte de la résistance électrique à travers la première source.

2. Détecteur (10) selon la revendication 1, dans lequel la détermination du niveau de l'espèce moléculaire gazeuse sur la base des signaux de sortie générés par l'appareil de surveillance de source (27) ajuste efficacement la détermination du niveau pour le rayonnement de la première source (20).

3. Détecteur (10) selon la revendication 1, dans lequel le second capteur de rayonnement (42) comprend une photodiode.

4. Détecteur (10) selon la revendication 1, dans lequel la seconde source (22) comprend une diode électroluminescente ou une diode à laser.

5. Procédé de surveillance d'un niveau d'une espèce moléculaire gazeuse dans un flux de gaz respirable avec un détecteur (10) qui comprend une première source (20), une seconde source (22), une optique de source (24), une optique de détecteur (38), un premier capteur de rayonnement (40), un second capteur de rayonnement (42) et un processeur (36), le procédé comprenant :

l'émission d'un rayonnement électromagnétique d'infrarouge moyen par la première source (20) ;

l'émission d'un rayonnement électromagnétique du proche infrarouge par la seconde source (22) ;

la combinaison avec l'optique de source (24) du rayonnement électromagnétique d'infrarouge moyen émis par la première source (20) et du rayonnement électromagnétique du proche infrarouge émis par la seconde source (22) en un courant coaxial ;

l'acheminement avec l'optique de source (24) du faisceau coaxial en travers d'un trajet d'écoulement (18) du flux de gaz respirable qui communique avec une voie aérienne d'un sujet ;

la division avec l'optique de capteur (38) d'un rayonnement électromagnétique dans le faisceau coaxial qui a traversé le trajet d'écoulement (18) en un premier rayonnement qui comprend le rayonnement électromagnétique d'infrarouge moyen et le second rayonnement qui comprend un rayonnement électromagnétique du proche infrarouge ;

la génération avec le premier capteur de rayonnement (40) de signaux de sortie acheminant des informations en rapport avec un paramètre du rayonnement électromagnétique d'infrarouge moyen dans le premier rayonnement ;

la génération avec le second capteur de rayonnement (42) de signaux de sortie acheminant des informations en rapport avec un paramètre du rayonnement électromagnétique du proche infrarouge dans le second rayonnement ; et

la détermination par le processeur (36) d'un niveau d'espèce moléculaire gazeuse dans le flux de gaz respirable du trajet d'écoulement (18) sur la base des signaux de sortie générés par le premier capteur de rayonnement (40) et le second capteur de rayonnement (42) de sorte que les signaux de sortie générés par le second capteur de rayonnement (42) soient mis en oeuvre pour compenser une perte optique à travers le trajet d'écoulement (18) dans les signaux de sortie générés par le premier capteur de rayonnement (40) ;

caractérisé en ce que le détecteur comprend en outre un appareil de contrôle de source (27), dans lequel le procédé comprend en outre la génération avec l'appareil de contrôle de source (27) de signaux de sortie acheminant des informations en rapport avec la résistance électrique

à travers la première source (20), et
dans lequel la détermination du niveau de l'espèce moléculaire gazeuse est en outre basée sur les signaux de sortie générés par l'appareil de contrôle de source (27) pour tenir compte de la résistance électrique à travers la première source (20).

6. Procédé selon la revendication 5, dans lequel la détermination du niveau de l'espèce moléculaire gazeuse sur la base des signaux de sortie générés par l'appareil de surveillance de source (27) ajuste efficacement la détermination de niveau pour le rayonnement de la première source (20).

7. Procédé selon la revendication 5, dans lequel le second capteur de rayonnement (42) comprend une photodiode.

8. Procédé selon la revendication 5, dans lequel la seconde source (22) comprend une diode électroluminescente ou une diode à laser.

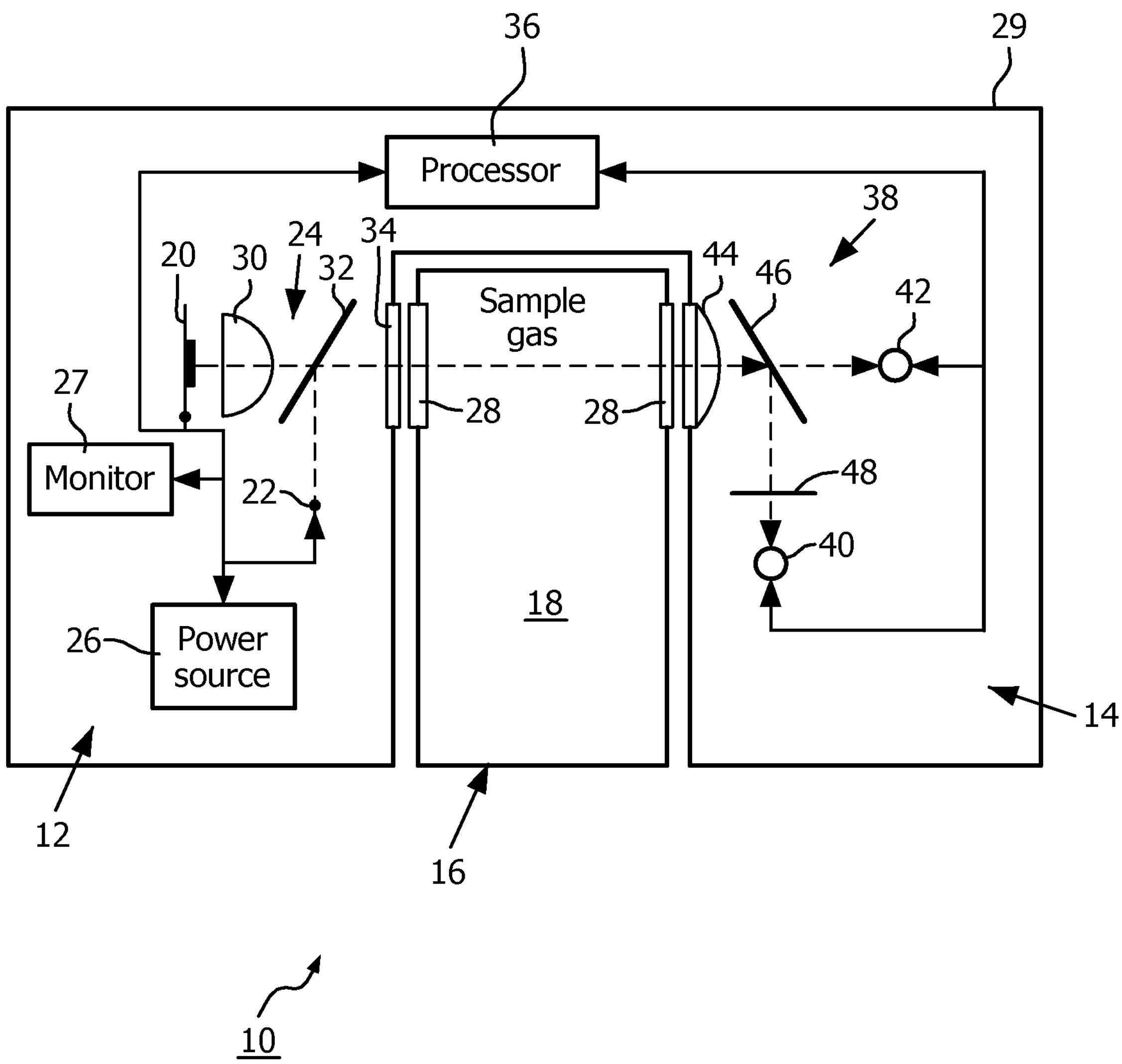
36
29
Processor
38
20
30
24
32
34
44
46
42
Sample
gas
27
28
28
Monitor
22
48
40
18
26
Power
source
14
12
16
10

FIG. 1

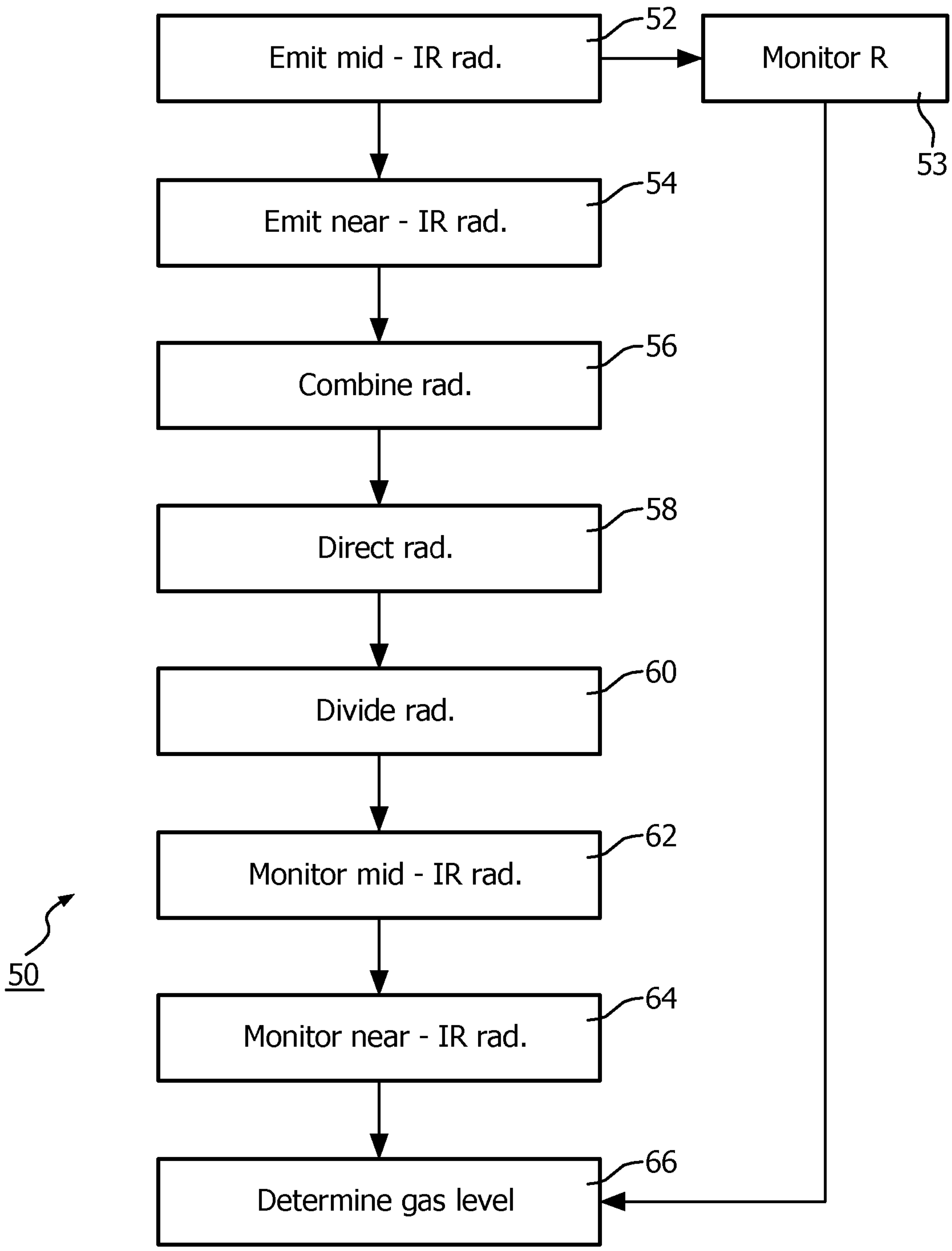
Emit mid - IR rad.
52
Monitor R
53
Emit near - IR rad.
54
Combine rad.
56
Direct rad.
58
Divide rad.
60
Monitor mid - IR rad.
62
50
Monitor near - IR rad.
64
Determine gas level
66

FIG. 2

REFERENCES CITED IN THE DESCRIPTION

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